Air bubble to air clathrate hydrate transformation in polar ice sheets

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Air bubbles are trapped in plar ice sheets when snow changes into ice. The bubbles are compressed with depth by an ice load and gradually transform into clathrate hydrates below the depth at which the bubble pressure exceeds the dissociation pressure of air clathrate hydrates. The transition from air bubbles to air hydrates takes tens of thousands of years, and accordingly, bubbles and hydrates coexist within a several-hundred-meter-thick stratum of ice called the bubble-to-hydrate transition zone.

Air bubbles and air clathrate hydrates, hereafter air inclusions, in polar ice cores attract considerable interest because they provide the most direct record of past atmospheric gas compositions [e.g., Raynaud et al., 1993]. However, the processes of air clathration in polar ice sheets and hydrate decomposition in ice cores after drilling should be taken into account when considering both the methods and the interpretation of the gas analyses. Although it is considered that the air composition changes during the bubble to hydrate transformation [Ikeda et al., 1999], the transformation process, including the mechanism of clathration, remains poorly understood.

To better understand the processes within the transition zone, we determined the distributions of air inclusions and impurities in the Dome Fuji Antarctic ice core. Mapping the spatial distribution of air inclusions in thick ice sections reveals a considerable redistribution of the inclusions in terms of number and volume in the transition zone, implying that a considerable modification of the climate signals takes place. We also found a significant correlation between the distribution of air hydrates and that of salt inclusions, suggesting that salt inclusions induce the hydrate nucleation. The redistribution of air inclusions can be explained as follows. First, reflecting a non-uniform distribution of salt inclusions, clathrate hydrates form locally. Subsequently, selective gas diffusion from air bubbles to clathrate hydrates through the ice matrix occurs as proposed by Ikeda and others [1999]. As a result, the spetial ditribution of air inclusions changed.

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